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EMG control of Prosthesis

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NATURAL CONTROL OF KEY GRIP AND PRECISION GRIP MOVEMENTS FOR A MYOELECTRIC PROSTHESES

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Abstract

Hand prosthesis function is augmented when the user can employ lateral grasp as well as traditional palmer grasp. Our goal in this investigation was to enable the below-elbow (BE) prostheses user to switch between and use these grasp modes in a natural and reliable manner. We recorded the EMG from residual muscles (*flexor dig; ext. dig; flex. pollicis longus; ext. pollicis longus*) involved in these grasp activities in an adult subject with below elbow (BE) amputation while she contracted her residual forearm muscles to mimic computer animations of different hand movements. To reduce crosstalk between the recordings from separate muscles, and to enhance the stability of the recording interface over the 30-day duration of the experimental sessions, we used chronically implanted percutaneous coiled wire electrodes implanted for 30 days (12 one-day sessions). Artificial Neural Network (ANN) pattern recognition techniques were used to extract voluntary command signals from the EMG signals. The mean absolute value (MAV) of the EMG signals was selected as a feature for training multilayer perceptrons. Initially, we trained ANNs having 5 hidden neurons using data from the 10^{th} and 12^{th} session individually (3 training sessions each). Three additional ANNs (sizes 4:7:4, 4:8:4, 4:9:4) were designed and trained (3 training sessions each) with combined data from experimental sessions 10 and 12. Subsequently, we separately tested the performance of these ANNs with data from the 9^{th}, 10^{th} and 12^{th} experimental sessions. While the results showed that data from different experimental days were substantially consistent, more reliable recognition of the grasp mode from any arbitrary test sample (i.e. taken from test sessions 9,10 or 12), was achieved when we used an ANN that was trained with representative samples from more than a single experimental day (e.g. using 10^{th} and 12^{th} experimental days data for training). This produced mean rates of recognition (averaged over the results from the three ANN training sessions with network size 4:8:4) of 97.6% key grip closing, 83.3% key grip opening, 85.7% precision grip closing, 96.4% precision grip opening, for the combined evaluation data from all test sets.

We conclude that intuitive operator selection, between key grip and precision grip modalities, is feasible for cases of BE amputation using recorded myoelectric signals.

INTRODUCTION

Loss of an arm transforms former simple tasks into difficult and tiresome challenges. Current prosthetic arms include body-powered devices and myoelectrically controlled hands. Although body powered devices have an advantage in providing the user with rough sensorial feedback through a control cable attached to a harness the bulkiness of this harness presents a serious drawback to the user [1]. Moreover, this approach has serious limitations for control of a multiple-degree of freedom artificial arm. Myoelectric prostheses offer better promise to achieve multiple-axis control in spite of inherent drawbacks such us maintenance problems, high weight, difficulty in operating and learning myoelectric control, inadvertent operation, and unreliability [1]. Myoelectric control is performed by means of the electrical activity of contracting muscles and, therefore, can be highly intuitive. Myoelectric multiple-axis control is feasible because the limit to the number of prosthesis functions is the amount of different contraction patterns produced by the user. However, control of present multiple axis prostheses is usually not natural from a motor-control point of view. To obtain more reliable and distinct contraction

patterns, prostheses users are frequently requested to produce patterns which do not correlate in a natural way with the movement replaced by the prosthesis [2,3]. As the number of prosthesis functions increases so does the amount of training required for its operation. Additionally, separability of EMG patterns (regardless of the type of feature space being used) tends to decrease, as more patterns are required. Consequently, unfamiliar patterns of contraction may not be able to replace the normal motor control strategies for manual dexterity. Previous work [4,5] suggested that phantom limb phenomena are evidence of complex motor control skills still present in amputees and might be useful for prosthesis control. However, the issue of whether intuitive and reliable motor patterns can be conditioned through training is still unsettled. The present work utilizes a novel training protocol based on biofeedback and visual tracking tasks in a below-elbow (BE) amputee. The goal of the training was to rehabilitate the subject's motor control skills to control finger opening and closing for two different grip modalities, key grip and precision grip. Due to the expected day-to-day variation in the evoked contraction patterns, we employed a pattern recognition system based on Artificial Neural Networks to discriminate the users intended grasp motion.

EXPERIMENTAL PROTOCOL

The subject was an adult female (age 33) with BE left arm amputation (which was her non-dominant hand) with strong phantom limb sensation meaning that she could perceive the movement in her phantom hand and fingers when contracting her residual muscles. Eight of the subject's residual muscles were chronically implanted with bipolar pairs of percutaneous coiled wire electrodes for the duration of the 30-day study. Prior to the implantation protocol, the condition of the selected residual muscles was assessed by Magnetic Resonance Imaging techniques (MRI). Based on the MRI evaluation, localization strategies were developed to identify each of the target muscles. A pair of electrodes for bipolar recording was inserted with 2cm tip separation into each of the following muscles: (1) Flexor Digitorum, (2) Extensor Digitorum, (3) Flexor Pollicis Longus, (4) Extensor Pollicis Longus, (5) Pronator Teres, (6) Supinator (7) Flexor Carpi Radialis, and (8) Extensor Carpi Radialis, though only the first 4 muscles were studied with regard to the present investigation. Subsequently, the experimental protocol was conducted as 12 one-day sessions distributed over the 30-day period. We used data obtained during 3 of the last experimental sessions (9^{th}, 10^{th}, 12^{th} sessions) for analysis since any benefits of training could be expected to be achieved nearer to the end of the protocol. Results from session 11 were omitted because the subject reported during the recordings that on some occasions she could not move the fingers of her phantom hand as if they were "asleep". This phenomenon did not appear to be present during the other experimental sessions, however.

The subject was seated facing a PC visual display (Fig.1), and she was requested to mimic with her phantom hand (as a kind of tracking task) animations of a hand performing key grip (closing-opening) and precision grip (closing-opening). She did this by contracting her residual limb muscles. The phantom hand movements were performed in 4 sets of 25 repetitions of the same grip task before the task was shifted to the other grasp type, In every case, the movements started with the fingers extended (hand open position). A pause of 1s was included between each consecutive movement repetition. Additionally, the subject was permitted to rest between sets at her request. The multiple-channel EMG signals together with a reference signal with information about the phasing and progression of the animation were collected and stored digitally. The EMG signals were amplified between 1000 and 10000 and band-pass filtered (10Hz-1KHz) before being sampled (2KHz).

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